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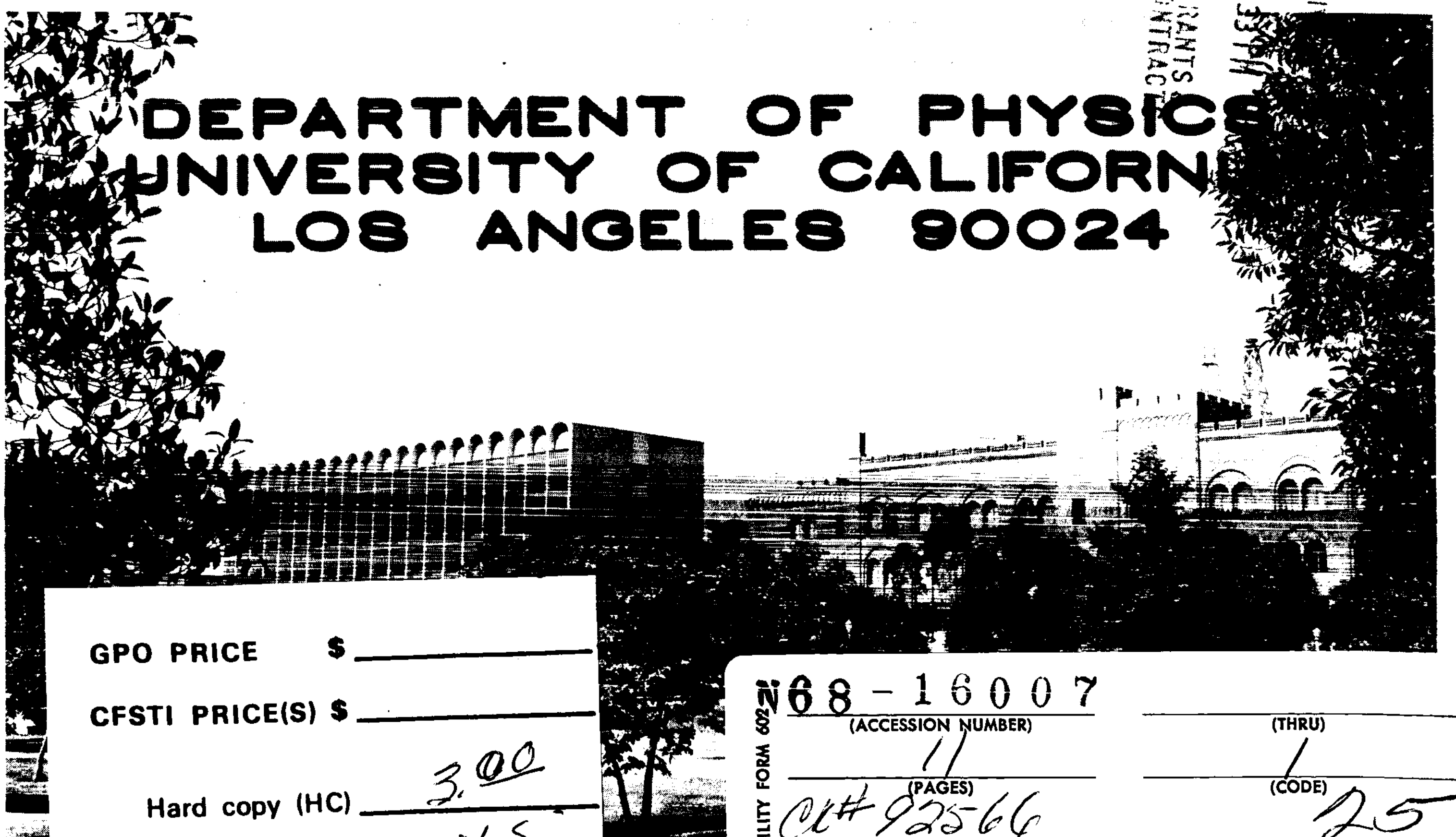

Parametric Coupling Between Drift Waves

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Drift waves are associated with temperature and density inhomogenities of a plasma in a magnetic field. In a cylindrical plasma, these waves are essentially ion acoustic waves propagating azimuthally, almost perpendicular to the magnetic field ($k_\perp >> k_{\parallel}$). The periodicity of the wave in the aximuthal direction gives rise to modes with integral relationship. In a stable plasma external excitation of these modes in the linear regime has been demonstrated.[1] We report in this letter preliminary experimental results describing the nonlinear phenomenon of parametric coupling between drift waves. This coupling involves the excitation of a drift wave of low mode number by a "pump" drift wave at a higher mode number which is externally excited. In this nonlinear process, both frequencies and wave numbers are conserved for the drift modes involved.

Experiments on parametric coupling between electron-plasma and ion acoustic oscillations have been reported although considerable disagreement still exists between the experimental and theoretical coupling coefficients.[2] Our experiment is conducted in a Cs plasma of a single ended Q device.[3] Excitation of the pump wave is achieved by modulating the potential of either a floating probe or a probe biased at about the plasma potential. The latter method appears to yield better coupling to the plasma in that a smaller oscillator voltage is required for parametric excitation. Drift waves are detected by Langmuir probes biased to collect ions. Both excitation and detection probes are placed at approximately the density gradient maximum.

For parametric excitation of the m = 1 mode at frequency ω, the oscillator used to drive the pump wave is set at frequency 2ω which is near $2\omega_r$, the resonant frequency for the m = 2 mode. Fig. 1 shows the variations of wave amplitudes of both the pump wave and the excited wave and the frequency width at half amplitude of the excited wave as the oscillator voltage is increased. The initial reaction of the stable quiescent plasma to an increase in voltage is the growth of the pump mode at 2ω. As the voltage is increased further, the pump mode reaches the threshold level for parametric excitation. At this point the fluctuation spectrum at ω narrows and increases in amplitude. This reaction is given by the frequency width at half amplitude of the frequency spectrum at ω. Representative frequency spectra at various stages of parametric excitation are given in Fig. 2. For a Cs plasma, the ranges of the parameters involved in parametric excitation are $8 \times 10^9\text{cm}^{-3} < n_o < 5 \times 10^{10}\text{cm}^{-3}$, $1.9\text{kG} < B < 3.2\text{kG}$, and $6\text{kHz} < \omega < 8\text{kHz}$.

In general, threshold for parametric excitation of a mode at frequency ω is dependent upon damping associated with this mode. We have determined experimentally the relation between damping and threshold, i.e., the coupling coefficient for parametric coupling between drift waves. The threshold for the wave at 2ω is represented by $n_{2\omega}/n_o$, the ratio of the density perturbation at the pump frequency to the local density. The damping associated with the excited mode is measured by applying an oscillator signal at ω_r through a tone burst generator on to the excitation grid and observing the damping of the drift wave on the Langmuir probe.[1] Variation of magnetic field, plasma temperature, density and etc., affects not only damping but also the threshold. Thus correlation between various values of damping and threshold is obtained and is given in Fig. 3. The results indicate approximately a linear change of damping rate with threshold, i.e.

$$K \frac{e\phi}{KT} = \frac{\omega_i}{\omega_r}$$

where $\frac{e\phi}{KT} = \frac{n_{2\omega}}{n_o}$ for drift waves and $\frac{\omega_i}{\omega_r}$ is the damping rate associated with the mode at ω. The coupling coefficient K is experimentally determined to be ~ 1.8. As expected, an increase in damping results in an increase in threshold for parametric excitation.

Beyond threshold, the amplitudes of both oscillations in Fig. 1 levels off, indicating that the excitations have reached saturation. Saturation of the pump wave may result either from limited probe coupling to the plasma because of sheath effects or from higher order nonlinear plasma effects. Both saturation of the pump wave and/or higher order nonlinear effects will limit the amplitude of the excited wave.

The direction of propagation of a drift mode is determined by noting the phase relation between signals received by probes displaced azimuthally by 90^o from one another. The pump wave and the excited wave are both identified as drift modes traveling in the electron diamagnetic drift direction.

Exact measurement of the frequencies pertinent to parametric excitation by a wave analyzer reveals that the excited mode frequency is exactly (within 10 Hz) half of the pump mode frequency. However the pump frequency is below the resonant frequency for the m = 2 mode. Therefore the excited mode frequency lies also below the resonant frequency of the m = 1 mode. The ratio of the frequency of the excited mode to that of the corresponding resonant mode ranges from 0.9 to 1.0.

Excitation of the lower modes by a pump mode at 3ω or 4ω is observed. A pump wave at 3ω excites drift waves at 1ω and 2ω. A pump wave at 4ω excites all three lower modes.

Basically the parametric process can be understood as the nonlinear interaction between the pump wave at 2ω and the fluctuating wave at ω producing an effect at the frequency ω which in turn enhances the fluctuating level of the original wave at ω. Quantitatively, this process can be described by a dispersion relation derived from Poisson's equation and the fluid equations governing the electrons and ions in the drift waves. Goldman and Weyl found that to second order in the applied field and for the case of plane waves parametric coupling between modes in the absence of collisions is negligible. However the inclusion of electron-ion collisions[4] should modify the coupling term and result in a dispersion relation describing our experimental results. We are now in the process of solving this nonlinear dispersion relation.

Acknowledgements

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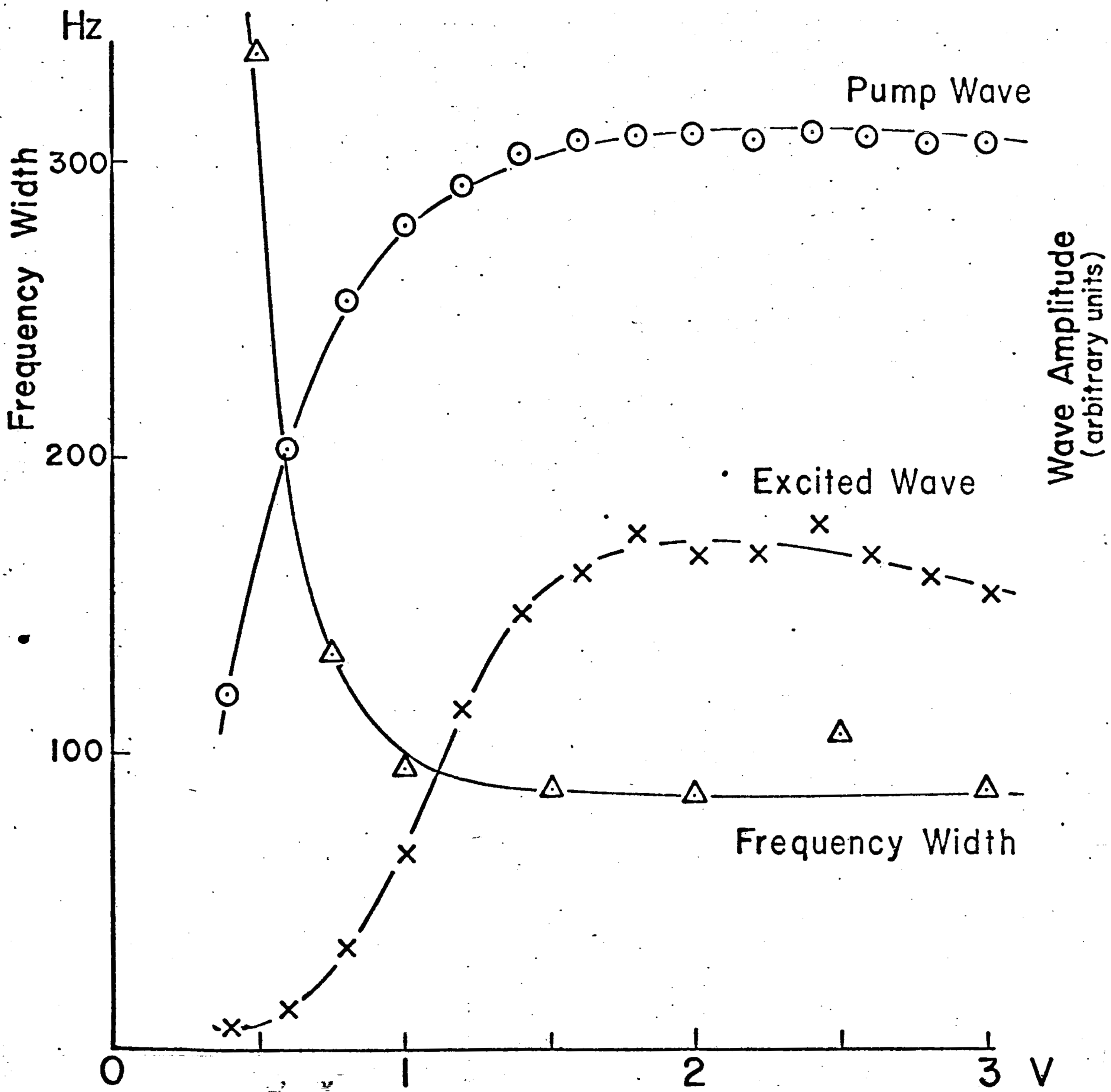

FIG.1 Frequency width and wave amplitudes as a function of oscillator voltage.

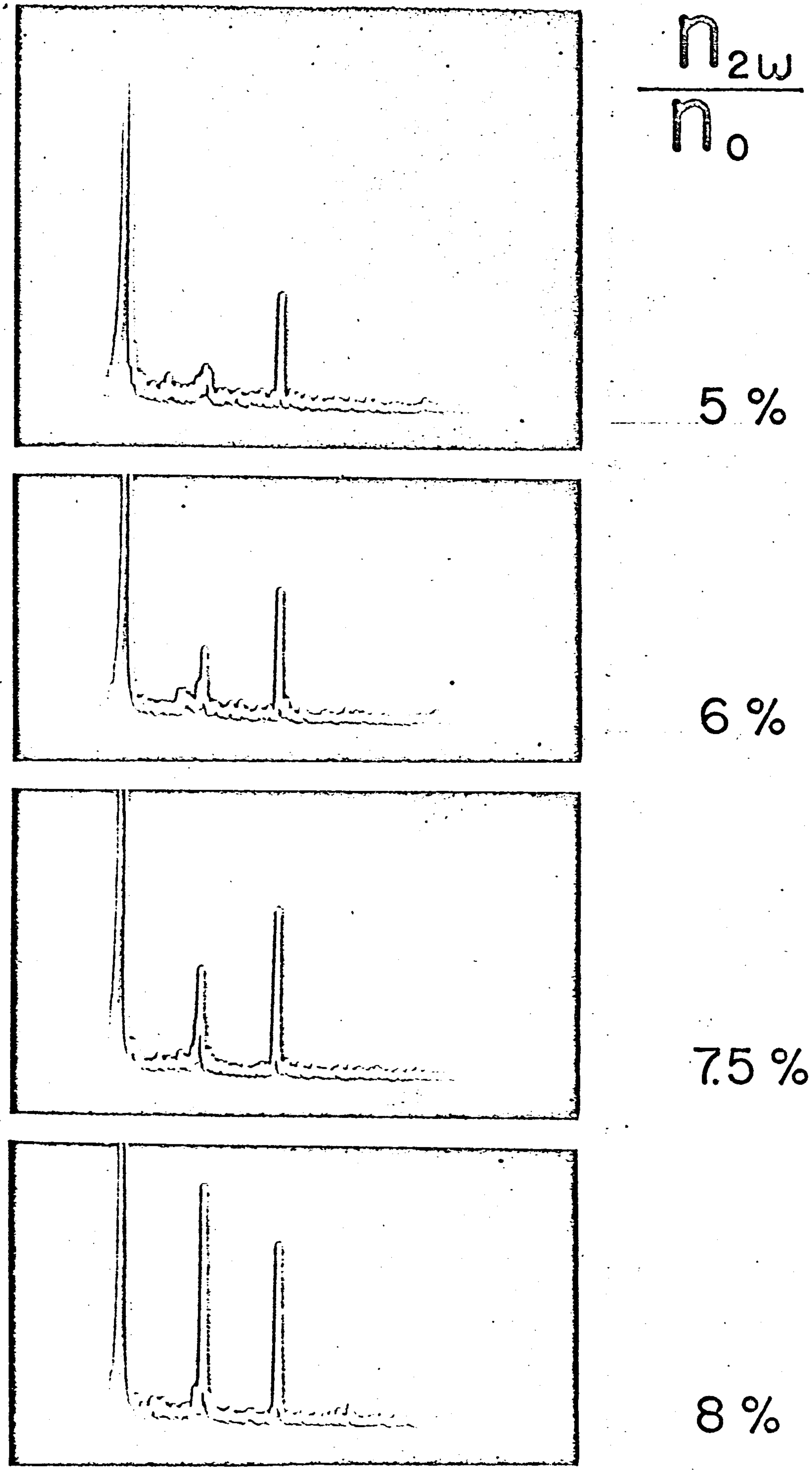

FIG. 2 FREQUENCY SPECTRA

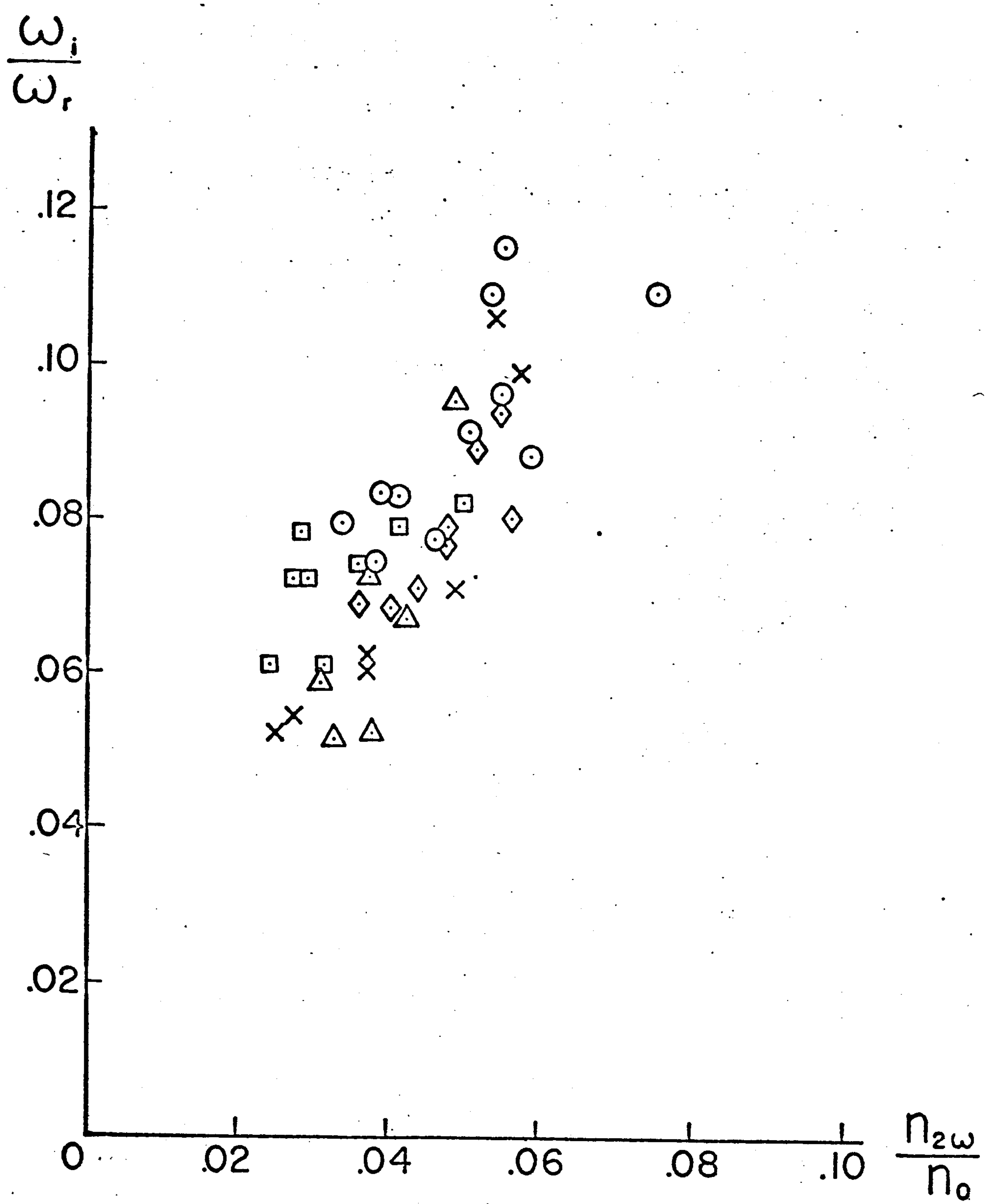

FIG. 3 Damping rate as a function of threshold.